The p-T coexistence line of nuclear matter: EOS results

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In Fisher's droplet model [1] a non-ideal fluid is approximated by an ideal gas of droplets. Thus, summing over n_A, the normalized yield of droplets of size A, gives the total pressure and the reduced pressure is:

$$\frac{p}{p_c} = \frac{T \sum n_A(\Delta\mu, E_{Coul}, T)}{T_c \sum n_A(\Delta\mu, E_{Coul}, T_c)}. \tag{1}$$

The coexistence line for finite neutral nuclear matter is obtained by summing with $n_A(\Delta\mu = 0, E_{Coul} = 0, T)$ in the numerator of Eq. (1) and $n_A(\Delta\mu = 0, E_{Coul} = 0, T_c)$ in the denominator.

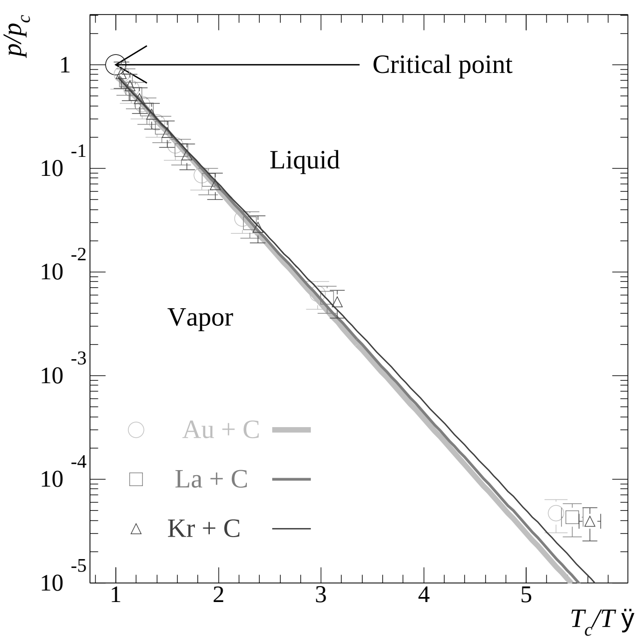

Figure 1: The reduced pressure-temperature phase diagram: points show calculations performed at the excitation energies below the critical point and lines show fits to Eq. (3).

Figure 1 shows the coexistence line of finite neutral nuclear matter, determined by an analysis of the EOS fragment yields of 1 AGeV Au, La, Kr + C. It is possible to make an estimate of the bulk binding energy of nuclear matter. Starting with the Clausius-Clapeyron equation

Table 1: Thermo(nuclear)dynamic properties

	T_c (MeV)	ΔH (MeV)	$\Delta E/A$ (AMeV)
Au	7.6 ± 0.2	19.4 ± 0.7	14 ± 1
La	7.8 ± 0.2	19.6 ± 0.7	14 ± 1
Kr	8.1 ± 0.2	19.5 ± 1.7	14 ± 1

$$\frac{\partial p}{\partial T} = \frac{\Delta H}{T \Delta V}. \tag{2}$$

Solving for the vapor pressure with $\Delta V = V_{vapor} - V_{liquid} \approx V_{vapor} = T/p$, one obtains $p = p_0 \exp(-\Delta H/T)$, which leads to

$$\frac{p}{p_c} = \exp\left[\frac{\Delta H}{T_c}\left(1 - \frac{T_c}{T}\right)\right]. \tag{3}$$

where ΔH is the molar enthalpy of evaporation. Equation (3) is empirically observed to describe several fluids up to T_c.

A fit of Eq. (3) to the coexistence line gives the ratio of $\Delta H/T_c$. The value of T_c [1] gives the molar enthalpy of evaporation of the liquid ΔH. ΔE is found via $\Delta E = \Delta H - pV$ with $pV = T$ using the average temperature from the range in Fig. 1, $\langle T \rangle \approx 4.9$ MeV. ΔE refers to the cost in energy to evaporate a single *fragment*. To determine the energy cost on a per nucleon basis ΔE is divided by the most probable size of a fragment over the temperature range in Fig. 1. Since the gas described by Fisher's model is an ideal gas of droplets, the most probable droplet size is greater in size than a monomer and in the region of the p-T coexistence line is ~ 1.05. The $\Delta E/A$ results are close to the nuclear bulk energy coefficient of 15.5 MeV. Table 1 lists the results.

References

[1] J. B. Elliott *et al.*, to be submitted to Phys. Rev. C (2002).